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OPTICAL SWITCH AND A CONTROL METHOD THEREOF

BACKGROUND OF THE INVENTION

The present invention relates to an optical communication system using optical fibers and more particularly to an optical switch using a technique of

5   microelectro mechanical systems (MEMS).

In an optical communication system, $N \times N$ optical switches are required at a relay point of communication network, which switches can connect arbitrary one of communication light beams transmitted

10   to N input ports through optical fibers to arbitrary one of N output ports and can switch these connections freely. In the past, to meet this requirement, light beams have once been converted into electrical signals and after being subjected to switching, the electrical

15   signals have been converted into light beams. In recent years, an optical switch has been developed which can perform switching of light beams while keeping them intact.

Available as a technique of optically

20   monitoring optical connections in an optical switch is JP-A-2001-117025 based on US application Serial No. 09/414,621 filed on October 8, 1999. The JP-A-2001-117025 discloses a configuration using optical translation units disposed before and after the optical

25   switch. The optical translation unit is an appliance

adapted to once convert a communication light beam into an electrical signal, confirm its intensity and waveform and thereafter reconvert the electrical signal into a communication light beam to transmit it to the

5   optical switch, thus assuring the quality of the communication light beam. In the JP-A, electrical signals inside the optical translation units disposed before and after the optical switch are compared to each other and the attitude of moving mirrors is so

10   controlled as to minimize the difference.

Highly accurate positioning is required of light beams incident upon output-side collimator lenses. In the event that a light beam deviates from the end face of an output-side collimator lens, optical

15   coupling fails. Even when entering the end face of the output-side collimator lens, the light beam will fail to couple optically or a large loss will be incurred if its incident angle is outside a proper range. In the initial stage of assembling, collimator lens arrays and

20   mirror arrays are positioned highly accurately.

However, as the temperature in the optical switch installation environment changes, the relative position between a collimator lens array and a mirror lens array changes and the optical coupling possibly

25   fails even if predetermined attitudes of the moving mirrors are maintained. Otherwise, a large loss will possibly be incurred. Or, when the temperature in the optical switch system per se rises owing to continuous

switching, the output of an electrical circuit changes and the moving mirrors will possibly fail to keep their predetermined attitudes.

5   In the method disclosed in the JP-A-2001-117025, the optical translation units before and after the optical switch are indispensable and disadvantageously, they make the construction complicated. Therefore, no reduction in the cost of the optical switch comes out. In addition, since two

10   optical translation units are installed in respect of individual N ports, totaling 2N, and as a result, the size of equipment increases.

BRIEF SUMMARY OF THE INVENTION

Accordingly, an object of the present

15   invention is to provide a compact optical switch which can solve the aforementioned problems encountered in the conventional example and can permit moving mirrors to keep optimum attitudes in correspondence with a change in temperatures in the installation environment

20   of the optical switch.

Another object of the invention is to provide an optical switch control method which does not branch and measure input and output light beams associated with all optical fibers preceding and succeeding the

25   optical switch and which can permit the moving mirrors to keep the optimum attitudes in correspondence with changes in temperatures in the installation environment

of the optical switch.

To accomplish the above objects, solving
means in the present invention can be carried out in
modes exemplified as below.

5 According to a first aspect of the invention,
there is provided an optical switch adapted to switch
communication light beams propagating through a
plurality of optical fibers and comprising a plurality
of input-side lenses to which input light beams connect

10 optically, a plurality of moving mirrors to which the
light beams passing through the input-side lenses
connect optically, a plurality of output-side lenses to
which the light beams going by way of the moving
mirrors connect optically, light emitting units for

15 generating light beams optically connecting to the
moving mirrors and light receiving units to which the
light beams coming from the light emitting units and
going by way of the moving mirrors connect optically,
wherein the plurality of input-side lenses include

20 first input-side lenses to which communication light
beams coming from first external units and passing
through the input-side optical fibers connect optically
and second input-side lenses to which the light beams
from the light emitting units connect optically, and

25 wherein the plurality of output-side lenses include
first output-side lenses for causing light beams
passing therethrough to optically connect to second
output-side optical fibers adapted to propagate the

communication light beams to second external units and
second output-side lenses for causing light beams
coming from the light emitting units and passing
therethrough to optically connect to the light

5   receiving units.

According to a second aspect of the
invention, there is provided, in the first aspect, an
optical switch comprising a mirror control unit for
correcting, on the basis of signals from the light

10 receiving units to which the light beams passing
through the second input-side lenses or the second
output-side lenses connect optically, control values
adapted to control angles necessary to move the moving
mirrors to which the light beams passing through the

15 first input-side lenses connect optically.

According to a third aspect of the invention,
there is provided an optical switch adapted to switch
communication light beams propagating through a
plurality of optical fibers and comprising a plurality

20 of input-side lenses to which input light beams connect
optically, a plurality of moving mirrors to which the
light beams passing through the input-side lenses
connect optically, a plurality of output-side lenses to
which the light beams going by way of the moving

25 mirrors connect optically, light emitting units for
generating light beams optically connecting to the
moving mirrors, and light receiving units to which the
light beams coming from the light emitting units and

going by way of the moving mirrors connect optically,
wherein the plurality of moving mirrors include a
plurality of first moving mirrors to which
communication light beams coming from first external

5 units and propagating through the input-side optical
fibers connect optically, and a plurality of second
moving mirrors to which the light beams from the light
emitting units connect optically.

According to a fourth aspect of the

10 invention, there is provided, in the third aspect, an
optical switch comprising a mirror control unit for
correcting, on the basis of signals from the light
receiving units to which the light beams going by way
of the second moving mirrors connect optically, control

15 values adapted to control angles necessary to move the
plurality of first moving mirrors.

According to a fifth aspect of the invention,
there is provided an optical switch optically
positioned between N input-side optical fibers and N

20 output-side optical fibers to switch communication
light beams propagating through the optical fibers and
comprising an input-side lens array having a plurality
of lenses optically coupled to the input-side optical
fibers, an output-side lens array having a plurality of

25 lenses optically coupled to the input-side optical
fibers, a primary mirror array having a plurality of
swingably supported mirrors adapted to reflect
communication light beams from the input-side lenses,

and a secondary mirror array having a plurality of
swingably supported mirrors adapted to reflect the
communication light beams reflected from the primary
mirror array, wherein the number of the input-side

5 lenses is N+2 or more, the number of the output-side
lenses is N+2 or more, the number of mirrors of the
primary mirror array is N+2 or more and the number of
mirrors of the secondary mirror array is N+2 or more.

        According to a sixth aspect of the invention,

10 there is provided, in the fifth aspect, an optical
switch comprising light receiving elements and a mirror
control unit for controlling positions of the mirrors
on the basis of signals from the light receiving
elements, wherein each of the input-side lens array and

15 the output-side lens array has a plurality of lenses
optically coupled to the light receiving elements and
each of the primary mirror array and the secondary
mirror array has a plurality of mirrors optically
coupled to the light receiving elements.

20   The light emitting elements not generating
communication light beams propagating through the
optical fibers are optically coupled to the light
receiving elements capable of receiving light beams
generated by the light emitting elements and the

25 coupling is switched by using the optical switch, and
the mirror control unit can use signals for controlling
mirrors intervening the coupling to control the mirrors
adapted to switch the communication light beams

propagating through the input-side optical fibers and output-side optical fibers.

Similarly, the number of mirrors of the primary mirror array adapted to reflect the communication light beams from the input-side lenses is set to at least N+2 or more and the number of mirrors of the secondary mirror array adapted to reflect the communication light beams reflected from the primary mirror array is set to at least N+2 or more.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a schematic perspective view of an optical switch according to a first embodiment of the invention.

Fig. 2 is a schematic perspective view of the optical switch according to the first embodiment of the invention.

Fig. 3 is a front view of a primary mirror array 6.

Fig. 4 is a block diagram showing the construction of a control system according to an embodiment of the invention.

Fig. 5 is a schematic perspective view of an optical switch according to a comparative example.

Fig. 6 is a schematic front view of a moving mirror of the optical switch in the comparative example.

Fig. 7 is a schematic sectional view of the
5 moving mirror of the optical switch in the comparative example.

Fig. 8 is a block diagram showing the construction of an optical switch control system in the comparative example.

10 DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the invention will be described hereunder in greater detail by making reference to the drawings. The present invention is in no way limited to configurations described in the
15 specification and is not prevented from being applied with present-day known techniques or newly developable known techniques.

Fig. 1 is a schematic perspective view of an optical switch according to a first embodiment of the
20 invention. The optical switch 1 comprises, as constituent components, an input-side collimator lens array 4 having arrayed input-side collimator lenses 3 optically coupled to a plurality of input-side optical fibers 2, primary and secondary mirror arrays 6 and 7
25 each having two-axially swingably movable, arrayed moving mirrors 5 and an output-side collimator lens array 10 having arrayed output-side collimator lenses 9

optically coupled to output-side optical fibers 8. The moving mirrors 5 of each of the primary mirror array 6 and the secondary mirror array 7 are inclined suitably to optically couple the input-side optical fibers 2 to

5   the output-side optical fibers 8 arbitrarily. The present embodiment will be described by way of example of an electrostatic drive system.

In the present embodiment, both the input-side optical fibers 2 and the output-side optical

10 fibers 8 are 32 in number, thus indicating an optical of 32×32 channels. But, the number of collimator lenses in each of the input-side collimator lenses 3 and the output-side collimator lenses 9 is 36 and similarly, the number of moving mirrors 5 in each of

15 the primary mirror array 6 and the secondary mirror array 7 is 36. The plurality of input-side collimator lenses 3 include a plurality of first input-side lenses to which communication light beams coming from first external units and propagating through the input-side

20 optical fibers 2 connect optically and a plurality of second input-side lenses to which light beams from laser diodes 11 representing light emitting units connect optically. Then, the plurality of output-side collimator lenses 9 have a configuration including a

25 plurality of first output-side lenses to which light beams passing therethrough optically connect to first output-side optical fibers 8 adapted to propagate the communication light beams to second external units and

a plurality of second output-side lenses for optically connecting the light beams coming from the light emitting units and passing therethrough to light receiving units.

5   The optical switch includes, as the light emitting units, laser diodes serving as light emitting elements. Also included as the light receiving units are photodiodes serving as light receiving elements. In a specified example, four laser diodes 11

10 (hereinafter indicated as LD's) are coupled to the input-side collimator lenses 3 at four corners and similarly, photodiodes 12 (hereinafter indicated as PD's) are coupled to four corners of the output-side collimator lens array 10. In the illustrated example,

15 the plurality of first input-side lenses and the plurality of first output-side lenses are each 32 in number and the plurality of second input-side lenses and the plurality of second output-side lenses are each 4 in number.

20   Hereinafter, the laser beam from the LD 11 will be termed a measuring light beam 13 in order that it can be discriminated from the communication light beam. Further, the moving mirrors at four corners of primary mirror array 6 which are used for reflecting

25 the measuring light beams 13 will be termed primary measuring mirrors 110 and the moving mirrors at four corners of secondary mirror array 7 will be termed secondary measuring mirrors 120.

Then, there is provided a mirror control unit 14 (Fig. 4) for correcting, on the basis of signals from the photodiodes 12 representing the light receiving units to which the light beams passing

5 through the plurality of first input-side lenses and the plurality of first output-side lenses connect optically, control values adapted to control angles necessary to move the moving mirrors to which the light beams passing through the plurality of first input

10 lenses connect optically.

Further, in the above configuration, there are provided the laser diodes 11 representing light emitting units for generating light beams connecting optically to the moving mirrors and the photodiodes 12

15 representing light receiving units to which the light beams coming from the light emitting units and going by way of the moving mirrors connect optically. The plurality of moving mirrors can be formed as having a plurality of first moving mirrors to which the

20 communication light beams coming from the first external units and propagating through the input-side optical fibers connect optically and a plurality of second moving mirrors to which the light beams from the light emitting units connect optically. Then, the

25 configuration can be defined as having the mirror control unit 14 for correcting control values adapted to control angles necessary to move the plurality of first moving mirrors on the basis of signals from the

light receiving units to which the light beams going by
way of the second moving mirrors connect optically.

As described above, the plurality of lenses
and the plurality of swingably supported mirrors are
5   provided, part of the plurality of lenses optically
couple to the optical fibers, part of the plurality of
lenses optically couple to the light emitting elements
not generating the communication light beams
propagating through the optical fibers, and part of the
10   plurality of lenses optically couple to the light
receiving elements capable of receiving light beams
generated by the light emitting elements.

Firstly, a method of controlling the moving
mirrors 5 of the primary mirror array 6 and secondary
15   mirror array 7 will be described.

An instance will first be described in which
with the optical switch assembled, a slight positional
difference takes place between the collimator lens
array and the mirror array. In addition, it is not
20   always held that all of the individual moving mirrors
have uniform rigidity as defined by the size of beams
supporting a mirror portion and the distance between
the mirror portion and a corresponding drive electrode.
Accordingly, even when a voltage is applied to incline
25   the moving mirror by using a mirror angle geometrically
calculated from an ideally arranged state and beam
rigidity and electrostatic attractive force calculated
from the design size, the mirror portion will not be

inclined by an intended angle and the input-side

optical fiber will not couple optically to the output-

side optical fiber at the maximum efficiency. Further,

because of a change in the temperature in the system, a

5   slight positional difference between the collimator

lens array and the mirror array takes place and the

above phenomenon is aggravated.

Accordingly, optimum inclination angles, that

is, optimum application voltages in individual

10   combinations of moving mirrors of the primary mirror

array and secondary mirror array must be mapped after

the optical switch has been assembled, in order that

the input-side optical fibers and the output-side

optical fibers can be coupled optically to each other

15   at the maximum efficiency. Hereinafter, this map

preparation work will be indicated as initial

adjustment work.

By making reference to Figs. 2 and 3, the

initial adjustment work will be described. Fig. 2 is a

20   schematic perspective view of the optical switch

according to the first embodiment of the invention.

For description to be given hereinafter, individual

lenses of the input-side collimator lens array 4 and

output-side collimator lens array 10 and individual

25   moving mirrors of the primary mirror array 6 and

secondary mirror array 7 will be designated by suffixed

reference numerals.

In the input-side collimator lens array 4,

lenses at four corners coupled to the LD's 11 are designated by 11-A to 11-D (for avoidance of complexity, the reference numeral denotation is partly omitted). Further, lenses for delivery of

5   communication light beams are designated by 4-1 to 4-32 (for avoidance of complexity, the reference numeral denotation is partly omitted). In the primary mirror array 6, to apply similar reference numerals to positions opposite to corresponding lenses, primary

10   measuring mirrors 110 are designated by 110-A to 110-D and moving mirrors are designated by 6-1 to 6-32 (for avoidance of complexity, the reference numeral denotation is partly omitted). In the output-side collimator lens array 10, lenses at four corners

15   coupled to the PD's 12 are designated by 12-A to 12D and lenses for receiving the communication light beams are designated by 10-1 to 10-32 (for avoidance of complexity, the reference numeral denotation is partly omitted). In the secondary mirror array 7, to apply

20   similar reference numerals to positions opposite to corresponding lenses, secondary measuring mirrors 120 are designated by 120-A to 120-D and moving mirrors are designated by 7-1 to 7-32 (for avoidance of complexity, the reference numeral denotation is partly omitted).

25   For clarity of the arrangement of mirror reference numerals, a front view of the primary mirror array 6 is shown in Fig. 3. In the input-side collimator lens array 4 opposing the primary mirror

array 6, lenses optically coupling to the individual
mirrors of primary mirror array 6 have numerals
suffixed to 4 which are arranged identically to those
in the primary mirror array. In the secondary mirror
5 array 7, mirrors to which moving mirrors of the primary
mirror array 6 approximately couple optically while
they are not inclined have numerals suffixed to 7 which
are arranged identically to those in the primary mirror
array. Further, in the output-side collimator lens
10 array 9 opposing the secondary mirror array 7, lenses
optically coupling to the individual mirrors of
secondary mirror array 7 have numerals suffixed to 10
which are arranged identically to those in the
secondary mirror array 7.

15   Firstly, the input-side collimator lens 4-1
is coupled to all lenses of output side collimator lens
array 10. The inclination angle of each of the moving
mirror 6-1 and the moving mirror 7-1 is first changed
slightly in both the X and Y axes to find a mirror
20 angle, that is, an application voltage which makes a
light beam from the input-side collimator lens 4-1
optically couple to the output-side collimator lens 10-
1 at the maximum efficiency. This work is sequentially
applied to the moving mirror 6-1 sequentially in
25 association with the moving mirrors 7-1 to 7-32.
Further, similar work is sequentially applied to the
individual input-side collimator lenses to prepare a
map of optimum application voltages as shown in Table 1

(hereinafter indicated as a lookup table).

Table 1   Lookup table (Example)

			OUTPUT-SIDE LENS ARRAY						
			7-1	7-2	7-3	..	7-30	7-31	7-32
INPUT- SIDE ARRAY	6-1	OUTPUT X=OV,Y=ΔV							
		INPUT X=OV,Y=ΔV							
	6-2								
	6-3								
	:								
	6-30								
	6-31								
	6-32								

If, after the lookup table is prepared
through the above initial adjustment work, the relative
position between the collimator lens array and the
5 mirror array does not change and the output of the
control circuit does not change, the optical coupling
between the input and output optical fibers can be
effected at the maximum efficiency with application
voltages identical to those described in the table.
10 However, as described above, as temperatures in the
optical switch installation environment change, the
relative position between the collimator lens array and
the mirror array changes or as temperatures in the
control circuit of optical switch system rise, the

output voltage changes. As a result, the optical coupling between the input and output optical fibers cannot be effected at the maximum efficiency even when output commands conformable to the lookup table are

5 delivered. The present invention can solve the above problems effectively at low costs.

Control construction will now be described with reference to Fig. 4. Fig. 4 is a block diagram showing a control system according to an embodiment of

10 the invention. In Fig. 4, reference numeral 14 designates a mirror control unit for controlling the primary mirror array 6 and the secondary mirror array 7, including an amplifier, a D/A converter, an operation device and a memory. The lookup table

15 described as above is stored in the memory of mirror control unit 14. Reference numeral 15 designates a processing unit for controlling the LD's 11 and PD's 12 to correct control of the primary mirror array 6 and secondary mirror array 7, including an A/D converter,

20 an operation device and a memory. The mirror control unit 14 and processing unit 15 constitute an optical switch control unit 16. The optical switch control unit 16 receives a signal for switching between the input-side optical fiber and the output-side optical

25 fiber from an external unit through an interface.

A method of controlling the optical switch will now be described with reference to Figs. 1, 2 and 4.

To sum up, a configuration is provided in which LD's 11 not generating communication light beam are coupled to two or more input-side collimator lenses 3 and similarly, PD's 12 not receiving communication

5 light beams are coupled to two or more output-side collimator lenses 9. By controlling the primary mirrors and secondary mirrors, the input-side collimator lenses coupled to the light emitting elements are optically coupled to the output-side

10 collimator lenses coupled to the PD's 12. At that time, inclination angles of respective movable mirrors in the primary and secondary mirror arrays are adjusted such that the outputs of the light receiving elements are maximized. Further, optical switching is effected

15 between two or more input-side collimator lenses and two or more output-side collimator lenses and then, inclination angles of the movable mirrors of the primary and secondary mirror arrays are adjusted such that the outputs of the PD's 12 are maximized

20 similarly. In this manner, the inclination angle adjustments of the movable mirrors of the primary and secondary mirror arrays are carried out and from the optimum inclination angles of the primary mirrors and secondary mirrors, changes in the relative position

25 between the collimator lens array and mirror array and changes in the output of the electrical circuit are calculated. Results of the calculation are reflected on the inclination angles of other movable mirrors for

switching the communication light beams so that the
inclination angle may be controlled to the optimum
inclination angle taking the changes in the relative
position between the collimator lens array and mirror
array and the changes in the output of the electrical
circuit. This will be described more specifically in
the following.

Laser beams 13 from the LD's 11 are reflected
by the primary measuring mirrors 110 at four corners of
the primary mirror array 6 and are further reflected by
the secondary measuring mirrors 120 at four corners of
the secondary mirror array 7 so as to be coupled
optically to PD's 12 at four corners of the output-side
collimator lens array 9. While constantly measuring
the optical outputs of the laser beams 13 by means of
the PD's 12, inclination angles of the individual
primary measuring mirrors 110 and those of the
individual secondary measuring mirrors 120 are changed
slightly in both the X and Y axes to find mirror
attitudes which maximize the outputs of the PD's 12.
In addition, switching is effected sequentially between
the primary measuring mirrors 110-A to 110-D and the
secondary measuring mirrors 120-A to 120-D to calculate
4×4=16 optimum mirror attitudes. Preferably, the
calculation may be carried out periodically.

As shown in Fig. 4, information about the 16
optimum mirror attitudes, upon which changes in the
relative position between the collimator lens array and

the mirror array and changes in the output voltage of
the control circuit are reflected, is reflected upon
the lookup table prepared through the initial
adjustment work to control the mirrors of the primary
5 mirror array 6 and secondary mirror array 7.

An example of a method for reflection upon
the lookup table will now be described. Firstly, the
16 optimum mirror attitudes determined by means of the
measuring mirrors are used for replacing the relative
10 position changes between the collimator lens array and
the mirror array or the output changes of the control
circuit with the relative position changes of secondary
mirror array 7 as viewed from the primary mirror array
6, that is, relative deformations of the secondary
15 mirror array 7. Subsequently, the shape of the
relatively deformed secondary mirror array 7 is
calculated using four measured points at four corners.
Further, from results of the calculation, coordinates
internal of the four corners corresponding to the
20 lookup table are calculated approximately. The most
simplified method is a linear approximation, according
to which the shape of the relatively deformed secondary
mirror array 7 is assumed to be a plane and the four
points at four corners are connected together by
25 straight lines to uniformly divide the inside of the
plane. In an alternative, results of measurement and
analysis precedently conducted are inputted in advance
to provide a curved surface and the shape of the

relatively deformed secondary mirror array 7 is assumed to be the curved surface and approximated in terms of the curved surface. For internal division, results of measurement and analysis precedently conduced are

5 inputted similarly in advance to provide a curved-surface shape and a method for division most liable to occur in the curved-surface shape is employed. The thus calculated coordinates are compared with the lookup table and voltage values in the lookup tables

10 are so controlled as to make the difference zero.

In this manner, the deflection angle of the mirror array for reflecting the communication light beams is corrected. For example, a voltage value representing a control value for obtaining a deflection

15 angle when a light beam is optically connected from one mirror of primary mirror array 6 to the secondary mirror array 7 is corrected starting with its initial value. In case the initial value has already been changed, the existing value can be updated. If the

20 secondary mirror array 7 is omitted and light beams going by way of the primary mirror array 6 optically connect to the output-side collimator lens array 10, a deflection angle of a mirror for optical connection from the primary mirror array 6 to one lens 9 of the

25 output-side collimator lens array 10 can be involved.

According to the invention, since the relative position change between the primary mirror array plane and the secondary mirror array plane or the

relative position change between the primary or
secondary mirror array plane and the collimator lens
array plane is determined and the drive amount of each
mirror is corrected on the basis of the thus determined

5   relative position change, the light emitting units and
light receiving units need not be provided by the
number of mirrors and therefore a compact optical
switch can be formed. From this point of view, the
configuration may preferably be such that measuring

10 light beams optically connect to mirrors positioned at
the outermost periphery of the mirror array.

In the embodiment as above, each of the
mirror control unit and the processing unit is provided
with the operation device and the memory but depending

15 on their capacities, the operation device and the
memory can be shared by these units.

While, in the foregoing embodiments, four
sets (4×4=16) of mirror combinations using four LD's
and four PD's are measured, the invention is not

20 limited thereto. With one set of mirror combinations,
optimum angles in X and Y axes of the mirror of the
primary mirror array 6 and that of secondary mirror
array 7 can be calculated. In other words, the shape
of secondary mirror array 7 after the relative

25 deformation, in which all deformations are replaced
with the relative change of the secondary mirror array
7, can be calculated from at least two sets of mirror
combinations. Accordingly, in the present invention,

it is indispensable that two or more input-side
collimator lenses optically couple to two or more
output-side collimator lenses without using
communication light beams and the optical coupling
5 state is fed back.

Further, in the foregoing embodiment, the
electrostatic drive system is used as the mirror
driving method but the invention is not limited thereto
and another drive method may be employed without
10 impairing the effects of the invention. For example,
in the case of a Lorentz force drive system, values of
current flowing through coils are described in the
aforementioned lookup table. On the basis of the shape
of secondary mirror array 7 after the relative
15 deformation determined through the method according to
the foregoing embodiment, the lookup table described
with coil current values is corrected. In other words,
as far as the drive system is capable of performing
control on the basis of the table prepared through the
20 initial adjustment work, the present invention can
fulfill its effects without being limited by that
system.

The construction of an optical switch of a
comparative example applied with MEMS technique is
25 shown in Figs. 5, 6 and 7. The optical switch 20 of
the comparative example is comprised of optical fiber
arrays, collimator lens arrays and mirror arrays. In
the mirror array, one-axially or two-axially

inclinational, moving mirrors are arrayed and in the optical fiber array and collimator lens array, the substantially same number of optical fibers and of collimator lenses as that of the moving mirrors are

5   arrayed similarly. The present inventors have studied this comparative example in the course of development of the present invention but will not intend to admit it as a prior art.

A light beam 23 formed after passing through

10   an input-side optical fiber 21 and an input-side collimator lens array 22 is reflected by a primary mirror array 24, again reflected by an opposing secondary mirror array 25 and passed through the other output-side collimator lens 26 to optically couple to

15   an output-side optical fiber 27. Inclination attitudes of moving mirrors 28 provided in the primary mirror array 24 and secondary mirror array 25 are changed and switching is effected through reflection at the individual mirrors.

20   Structurally, the moving mirror 28 is swingably supported in the air by means of a plurality of beams. Various kinds of methods for inclining the moving mirror 28 are conceivable but driving based on electrostatic force (hereinafter indicated as an

25   electrostatic drive system) and driving based on Lorentz force (hereinafter indicated as a Lorentz force drive system) are easy to electrically control. In the case of the Lorentz force drive system, coils are

typically mounted on the moving mirror 28 and the moving mirror 28 is disposed in an external magnetic field in which a magnet is arranged. By controlling currents flowing through the coils, the Lorentz force is controlled, so that beams supporting the mirror portion can be twisted and s stable attitude can be maintained by balance to torsional force of the beams supporting the mirror portion. A moving mirror structure of the electrostatic drive system will be described using Figs. 6 and 7. In the moving mirror 28, a plurality of electrodes 31 are formed at positions substantially opposing an optical reflection portion 29 swingably supported in the air by means of a plurality of beams 30 and a voltage is applied thereacross to generate electrostatic attractive force. By controlling this voltage, the electrostatic attractive force can be controlled, so that the beams 30 swingably supporting the mirror portion can be twisted and a stable attitude can be maintained under balance between twisting and torsional force of the beams.

The light beams incident on the output-side collimator lenses 26 are required of highly accurate positioning. When a light beam deviates from the edge of an output-side collimator lens 26, optical coupling fails. Even if the light beam enters the edge of the output-side collimator lens 26, the optical coupling will fail or a large loss will be incurred if the light

beam has an incident angle outside a proper range.
This is because a core portion (through which a
communication light beam propagates) of an optical
fiber connected to the edge of a collimator lens is

5   very thin amounting to a diameter of about $10\,\mu m$ and
even a slightly deviant incident beam becomes out of
the core portion. When the permissible loss is several
dB, the incident angle of a light beam upon an output-
side collimator lens 26 must have an accuracy of about

10   a degree of several of decimal fractions, though
depending on the kind of the lens and optical fiber.
Accordingly, the attitudes of the individual moving
mirrors 28 in mirror array which determine the position
and angle of light beams must be maintained with high

15   accuracies.

        The collimator lens array and the mirror
array are positioned highly accurately in the initial
phase of assembling. As a result, by applying a
predetermined current value in the case of the Lorentz

20   force drive system or a predetermined voltage in the
case of the electrostatic drive system, the moving
mirror 28 can be maintained at a predetermined attitude
and a light beam formed after being passed through a
predetermined input-side collimator lens 22 can be

25   coupled optically to a predetermined output-side
collimator lens 27. However, as the temperature in the
optical switch installation environment changes, the
relative position between the collimator lens array and

the mirror array changes, with the result that the optical coupling will possibly fail or a large loss will possibly be incurred even if the moving mirror 28 keeps the predetermined attitude. Otherwise, when

5 temperatures in the optical switch system per se rise owing to continuous switching, the output of the electrical circuit changes, thus causing the predetermined attitude of moving mirror 28 to possibly fail to maintain.

10 To avoid such phenomena as above, various control methods for controlling the attitude of moving mirror 29 highly accurately are conceivable. A method is shown in Fig. 8, according to which couplers are mounted to all input optical fibers and all output

15 optical fibers before and after an optical switch, so that part of a communication light beam is branched and measured and fed back for the attitude control of the moving mirror 28. A coupler 31 is mounted to an input-side optical fiber 21 to branch part of a communication

20 light beam so that the communication light beam before optical switching can be monitored. Similarly, a coupler 31 is mounted to an output-side optical fiber 27 to monitor the communication light beam after optical switching. From intensities of the

25 communication light beams before and after the optical switching, optimum attitudes of the primary mirror array 24 and the secondary mirror array 25 are calculated by means of a control unit 32. Results of

the calculation are reflected upon controlling of the
primary mirror array 24 and the secondary mirror array
25. This work is carried out constantly to permit the
input and output optical fibers couple to each other at
5   the highest efficiency. For avoidance of complexity,
only a single input optical fiber and only a single
output optical fiber are illustrated in Fig. 8. As
mentioned above, the couplers must be mounted to all of
the input optical fibers and all of the output optical
10 fibers in this method. In the method in which the
couplers are mounted to all input/output optical
fibers, indicating that in the case of N×N optical
switches, that is, N input ports, 2N couplers are
needed. The cost incurred for this is a cause of
15 raising the cost of the optical switch as a whole. In
addition, because of branching through the couplers,
losses in the input/output light beams increase. In
the event that the communication light beams decreases
in intensity, the communication light beams must once
20 be converted electrically, subjected to electrical
amplification and again converted into light beams.
The intervention of this amplification process, opto-
electric conversion equipments and electro-optic
conversion equipments are needed and these conversion
25 apparatus lead to high costs.

Contrary to this, in the construction of the
present embodiment, the demerits of the above
comparative example can be lessened and the positional

changes of the collimator lens array and mirror array and the output changes of the electrical circuit can be corrected without branching the communication light beams by using the couplers. Consequently, the number

5   of parts of the optical switch can be decreased. In addition, the loss caused by branching through the coupler can be suppressed.

Further, in the optical switch according to the present embodiment of the invention, the

10   communication light beam is not branched using the coupler and therefore, the optical switch can be compacted as compared to the conventional one.

Further, because of the elimination of the coupler, inexpensiveness can be assured in the optical

15   switch control method of the invention.

Furthermore, since the positional changes of the collimator lens array and the mirror array and the output changes of the electric circuit are measured by means of mirrors different from and independent of

20   mirrors for switching the communication light beams, the mirrors for switching the communication light beams need not be moved slightly. As a result, coupling of the communication light beams can be stable.

As a modified example of the foregoing

25   embodiment, the secondary mirror array 7 may be replaced with a reflection plate and it should be understood that the present invention can be applied effectively to such a case.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.